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Economic analysis of backyard agriculture and livestock farming in semi-urban areas of the central highlands of Mexico

Análisis económico de la agricultura y ganadería de traspatio en áreas semi-urbanas del Altiplano Central de México

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Abstract
In the backyard systems in urban and semi-urban areas of the central highlands of Mexico, agriculture and livestock activities are practiced. In order to know the behavior of the economic variables in these farms, a non-probabilistic sampling by quotas was carried out, using the snowball technique, which consisted of applying surveys to a total of 92 producers, which was designed to collect information on the general characteristics of the backyard, social, and economic system, as well as the products generated from agriculture and livestock. With the information collected, an inventory of the plant and animal species that are produced in the backyard system was made, in addition to estimating economic income, variable costs, fixed costs, total costs, profits and the benefit-cost ratio for carrying out livestock activities agriculture or both in backyard systems. It was found that farmers have an average space in the backyard of 360.5 m^2 to carry out activities of agriculture, livestock or both. Farmers who carry out agriculture and livestock activities generate higher income and economic profits, compared to those who only carry out one activity, obtaining a benefit of 27.44 cents for each dollar invested, compared to 16.64 and 18.00 cents for developing the activity agriculture and livestock respectively. The agricultural and livestock activity in the backyard systems of the highlands of Mexico, represent an option to generate economic income for families, and generate food products for self-consumption and reduce expenses for food purchases in the family nucleus.
Keywords: producers' market; benefit ratio; cost; profitability; backyard systems; agriculture; livestock; farmers; economics; highlands; Mexico

Resumen
En los sistemas de traspatio en áreas urbanas y semi urbanas del Altiplano Central de México se practican actividades de agricultura y ganadería. Con el objetivo de conocer el comportamiento de las variables económicas en estos sistemas de producción, se realizó un muestreo no probabilístico por cuotas, utilizando la técnica bola de nieve, que consistió en aplicar encuestas a un total de 92 productores, la cual se diseñó para colectar información sobre las características generales del sistema de traspatio, sociales, y económicas, así como los productos generados de la agricultura y ganadería. Con la información colectada se realizó un inventario de las especies vegetales y animales que se producen en el sistema de traspatio, además de estimar

ingresos económicos, costos variables, costos fijos, costos totales, utilidades y la relación beneficio costo por realizar actividades de ganadería, agricultura o ambas en los sistemas de traspatio. Se encontró que los productores tienen en promedio un espacio en los patios de sus casas de 360.5 m^2 para realizar actividades de agricultura, ganadería o ambas. Los productores que realizan actividades de agricultura y ganadería generan mayores ingresos y utilidades económicas, respecto a los que solo realizan una actividad, obteniendo un beneficio de 27.44 centavos de dólar por cada dólar invertido, respecto a los 16.64 y 18.00 centavos por desarrollar la actividad de agricultura y ganadería respectivamente. La actividad agrícola y ganadera en los sistemas de traspatio del altiplano del Estado de México representan una opción para generar ingresos económicos para las familias, y generar productos alimenticios de autoconsumo y reducir gastos por compra de alimentos en el núcleo familiar.

Palabras clave: mercado de productores; relación beneficio; costo; rentabilidad; sistemas de traspatio; agricultura; ganadería; granjeros; economía; altiplano; México

1. Introduction

Agricultural and livestock production in urban and peri-urban backyard systems is economically important around the world and in Mexico. The available spaces such as patios, roofs, and backyards are used to produce food of plant or animal origin, or both (Bellwood-Howard *et al.,* 2018). It is reported that they are of importance because they are a way to improve food security, generate a constant supply of vegetable and meat products for self-consumption, and economic income that serve to cover basic expenses of the families (Di Pillo *et al.,* 2019). Additionally, they are a model for the conservation of native genetic varieties, whose economic, scientific, and cultural potential makes them valuable (Botero *et al.,* 2018).

Backyard production systems in rural areas have been better described worldwide, while studies carried out on systems in urban and peri-urban areas focus mainly on the description of socioeconomic characteristics (Alemayehu *et al.,* 2011), type of generated plant and animal products, urban landscape planning and development (Bellwood-Howard *et al.,* 2018), challenges faced by urban and peri-urban backyard systems in relation to water resources, alternative land uses, and contribution to food security and poverty reduction (Vagneron, 2007; Kutiwa *et al.,* 2017). In the last decade in capitalist and socialist countries, studies of backyard food systems in both rural and urban areas have become important, due to the need to achieve food sovereignty, but to achieve this objective it is necessary to carry out research that not only describes the system but quantifies the evaluation of the system to find proposals to improve the production and availability of food (Cameron, 2014).

In Mexico, most of the studies also focus on the importance of backyard systems in rural areas, describing the diversity of plant and animal species that make up the production unit, food generation (González *et al.,* 2013; Olvera-Hernández *et al.,* 2017), emission of pollutants (Hernández-Zepeda *et al.,* 2017), and their contribution to food safety. Furthermore, the studies related to the economic evaluation have focused on the production of chicken meat and eggs in backyard systems, because they are the most frequently found in rural, urban, and semi-urban areas, as they are considered profitable (Cuca-García *et al.,* 2015). It is also possible to highlight studies on small-scale milk production systems and their economic and job-generating potential (Salinas-Martínez *et al.,* 2020).

However, although it is generally reported that backyard systems contribute to the family economy, it is necessary to generate quantitative information regarding production costs, economic savings in the basic basket from self-consumption, income from the sale of products, and profits and benefit-cost ratio of backyard systems, to generate development support strategies for these production systems. Therefore, the objective of this study was to make a socioeconomic analysis in relation to income, production costs, profits, and benefit-cost ratio of backyard production units in semi-urban areas in the Central Highlands of Mexico.

2. Materials and methods

Study area

This study was carried out in a semi-urban area belonging to the Central Highlands of Mexico, which includes the municipalities of Almoloya de Juárez, Calimaya, Coatepec Harinas, Temoaya, Tenango del Valle, Toluca, Metepec, Aculco, and Ixtlahuaca, belonging to the State of Mexico. They are located between 19°17'29 north latitude and 99°39'38 west longitude, with a sub-humid climate, average annual rainfall of 747.5 millimeters, and an average annual temperature of 11.5 °C (CNA, 2021).

Study period and interview surveys

A cross-sectional study was carried out in 2017 from July to October, through the application of surveys to backyard farmers. For this, they were designed to record information on general data in backyard production systems, social characteristics of the producers, agricultural component that involved cultivated species, livestock component, which referred to the animal species raised, agricultural and livestock management activities carried out in the production unit, quantity of agricultural and livestock products obtained from the system, costs of inputs used for agricultural and livestock production (labor, manure, fertilizers, seeds, food, vaccines, deworming, technical advice), and sale price of the products generated from 92 backyard production systems, dedicated to agricultural or livestock production, or both.

Sampling method

To learn the characteristics of the backyard production units, a non-probabilistic quota sampling was carried out, using the snowball technique which consists of selecting the backyard producers who can form a sample, in this case all the farmers who carry out agricultural, livestock or both activities in the backyards were selected. The snowball technique made it possible to find a farmer, who in turn provided the data of a third party to be interviewed, and so on, until the producers available to provide information were exhausted (Hernández *et al.,* 2006). The data related to socioeconomic information were analyzed with descriptive statistics using the PROC MEANS procedure of SAS 9.3.

Economic analysis

The 92 backyard production units were classified according to the activities carried out, agricultural, livestock, or both. The most important economic indicators in the production unit were calculated; the income from products sold, the potential unsold income, variable costs, fixed costs, total costs, profits following the methodology proposed by Espinosa-Garcia *et al.* (2010).

The income from products sold, corresponded to the sum of the income obtained for the sale of each product agricultural and livestock product generated in the backyard system. The potential unsold income corresponded to the sum of the economic value of the agricultural and livestock products that the producer used for self-consumption; that is, the total value of the products that were consumed at home and were not sold in some type of market.

The total average monthly income corresponded to the sum of the income from the products sold, plus the potential unsold income. Variable costs considered the sum of the expenditure on inputs directly related to production labor, manure, fertilizers, seeds, water, food, vaccines, deworming, and other expenses.

Fixed costs considered the depreciation of assets used for agricultural and livestock activities, such as corrals, livestock, irrigation system, greenhouses. Each asset was adapted to the years of useful life, according to the commercial value and physical state. In addition, 3% of the gross income from the sale of products was considered as an administration cost. This rule applies when an administrator is not hired in the production unit, as happens in backyard systems, where 100 % of the workforce is family.

$$Fixed\ costs = Depreciation\ costs + Administration\ costs$$

$$Depreciation = \frac{Initial\ asset\ value - Asset\ scrap\ value}{Years\ of\ useful\ life}$$

Total costs considered the sum of variable costs and fixed costs. Because in backyard production systems, 100% of the labor is family, variable costs, fixed costs, total costs, profit, and benefit-cost ratio were calculated twice; one calculation considered the labor cost of work and administration and another calculation did not consider these expenses (Posadas-Domínguez *et al.,* 2013).

$$Total\ cost = variable\ costs + fixed\ costs$$

The profit was calculated by the difference between the total income and total production costs, while the benefit-cost ratio refers to the profit divided by the total production costs, multiplied by 100 (Espinosa et al., 2020). For the economic analysis, the MXN - USD exchange rate for the year 2017 was considered, which was $17.46 according to data from the Bank of Mexico, to transform pesos into dollars.

$$Cost\ benefit = \frac{Utility}{Total\ cost} * 100$$

3. Results and discussion

The socioeconomic characteristics showed that the average age of the people responsible for the backyard production units corresponds to adulthood, with studies completed up to secondary or junior high school. The family structure is made up of both a man and woman heads of the family, children, and in some cases by some relatives such as nephews, grandchildren, parents, in-laws, brothers, daughters-in-law, and sons-in-law (Table 1). In backyard production systems of urban and semi-urban areas, agricultural activities, livestock farming, or both are carried out, and it is possible to find them all over the world (Alemayehu *et al.,* 2011; Bellwood-Howard *et al.,* 2018; Di Pillo *et al.,* 2019), including Mexico (Cuca-Garcia *et al.,* 2015). The producers of urban and semi-urban areas in the Mexican Highlands who carry out backyard activities are young people, adults, and the elderly, as it is an activity in which most of the family members participate (Garcia *et al.,* 2012; Elkashef *et al.,* 2016) .

The person responsible for directing the activities is an adult, who has the greatest availability of time to tend to plants and animals, or family leaders who seek an alternative to generate extra income, a form of savings, and to generate food. The same happens in other Latino American countries like Colombia, where the age of producers in urban and semi-urban areas ranges from 33 to 72 years (Botero *et al.,* 2018). The average schooling of the producers is secondary or junior high school, and the number of family members is 5.3; higher than the 3.6 average number of members of the family nucleus in Mexico (INEGI, 2018). The producers have from 17 to 20 years' experience in carrying out backyard livestock farming and agriculture, since in backyard systems in Mexico, and countries such as Chile (Di Pillo *et al.,* 2019) and Ethiopia (Alemayehu *et al.,* 2011), labor is family-based, and the activities are learned from childhood. So, family members acquire work skills in agriculture and livestock farming from an early age (Álvarez-Calderón *et al.,* 2017).

Table 1. *Socioeconomic characteristics of the producers of backyard systems in semi-urban areas of the Central Highlands of Mexico*.

Tabla 1. *Características socioeconómicas de los productores de sistemas de traspatio en zonas semiurbanas del Altiplano Central de México*.

Characteristic	Mean	SD	Minimum	Maximum	VC
Age of the producer (years)	51.3	12.6	36	65	24.70
Schooling (years)	9.2	5.1	3	16	56.6
Number of family members	5.3	0.8	2	9	36
Surface area dedicated to the backyard (m^2)	360.5	37.3	48	1252	10.36
Years dedicated to livestock farming	20	5.6	3	27	28
Years dedicated to agriculture	17	4.8	4	30	28.23

Note: VC = Variation coefficient; SD = Standard deviation.

Nota: CV = Coeficiente de Variación; DE= Desviación estándar.

The size of the lots where backyard livestock farming and agriculture are carried out in this region of Mexico allows producers to have a diversity of plants and animals. Regarding agricultural production, producers use it for self-consumption; it is a way of having fruits, vegetables, herbs of daily use in Mexican gastronomy, medicinal plants, and also part of the production is destined for trade (Olvera- Hernández *et al.,* 2017), mostly informal or outside the classic marketing circuits. Regarding livestock farming, chicken production (meat and eggs) is the one that is practiced in the highest percentage in the study area. This phenomenon in common in the backyard systems of Mexico (Itza-Ortiz *et al.,* 2016) and places such as Chile and Colombia (Botero *et al.,* 2018; Di Pillo *et al.,* 2019) where the importance of this species is reported. This is because few inputs are used for production, which causes a lower cost in the maintenance of the animals, the facilities are made with material from the region, and they are easy to sell without intermediaries. This type of practice has a similar scheme to short marketing circuits. The surface of the lots, destined to the cultivation of plants and breeding and handling of animals, on average corresponds to 360.5 m^2. Those responsible for the backyard systems have dedicated an average of 20 years to carrying out livestock farming activities and 17 years to agricultural activities. The surfaces destined for agricultural and livestock activities are greater than those available in other cities of the world, therefore, an adequate use of backyards represents a strategy to increase the production of backyard systems (Lovell, 2010).

Table 2. lists the plants most frequently found in backyard units, in which the cultivation of fruit trees characteristic of temperate climates, forage plants used for animal feed, vegetables and medicinal plants stand out. Regarding the animal species, it was found that broilers and laying hens were found most frequently, with an average percentage of 42.1% of the 38 production units dedicated to livestock farming and the combination of agriculture with livestock farming. Sheep and bovine species were found in a frequency of 18.42%, followed by rabbits with 13.15%, and in a lesser proportion the porcine species with a frequency of 7.8%.

Table 2. *Varieties of plants and animals found in backyard systems in semi-urban areas of the Central Highlands of Mexico*.
Tabla 2. *Variedades de las plantas y animales encontrados en los sistemas de traspatios en áreas semi urbanas del Altiplano Central de México*.

Fruit trees	**Vegetables**	**Medicinal plants**
Apple *(Malus domestica)*	Lettuce *(Lactuca sativa)*	Chamomile *(Chamaemelum nobile)*
Peach (*Prunus persica)*	Beet *(Beta vulgaris)*	Spearmint *(Mentha spicata)*
Loquat *(Eriobotrya japonica)*	Cucumber (*Cucumis sativus*)	Rue *(Ruta graveolens)*
Walnut *(Juglans regia)*	Coriander (*Coriandrum sativum*)	**Animals**
Avocado *(Persea americana)*	Epazote (*Dysphania ambrosioides*)	Milk cows
Black cherry *(Prunus salicifolia)*	Tomato (*Solanum lycopersicum*)	Beef cattle
Plum *(Spondias purpurea)*	Green tomato (*Physalis philadelphica*)	Pigs
Mexican hawthorn *(Crataegus mexicana)*	Broccoli (*Brassica oleracea*)	Sheep
Pomegranate *(Punica granatum L)*	Garlic *(Allium sativum)*	Goats
Fig (*Ficus carica*)	Peas *(Pisum sativum)*	Rabbits
Lemon (*Citrus lemon*)	Radish *(Raphanus sativus)*	Laying hens
Forages	Colliflower *(Brassica oleracea)*	Broilers
Corn (*Zea mays*)	Manzano pepper *(Capsicum pubescens)*	Turkeys
Alfalfa *(Medicago sativa)*	Zucchini *(Cucurbita pepo)*	
Oats *(Avena sativa)*	White goosefoot *(Chenopodium album)*	

On the other hand, in the production units, 100% of the producers consume between 16 to 30% of the total vegetables and animal products they generate, such as fruits, vegetables, medicinal plants, eggs, milk, meat, and processed products (cheese, cottage cheese, barbacoa, carnitas, chorizo), and the rest of the production is sold: 81.54% among neighbors, friends, and acquaintances, 10.86% in local street markets, 4.34% to intermediaries, and 3.26% to wholesalers.

The production of sheep, cattle, and rabbits is a practice that is carried out in the study area, unlike other backyard systems (Vargas-López *et al.,* 2017; Botero *et al.,* 2018), since the management of these animals requires more care regarding food and facilities. Furthermore, the temperate climate conditions allow the production of wool sheep, especially fit for meat production, where culturally, the area is characterized for the consumption of mutton, mainly in barbacoa (typical Mexican dish where the meat is slowly cooked with steam heat and buried underground) as highlighted by Orona-Castillo *et al.* (2014). The production of pigs is the one that is carried out less frequently, since although food waste from markets, home, bakeries etc. is used for to feed them, the waste that is generated gives off an unpleasant smell for the neighbors. Thus, being in urban and semi-urban areas, the percentage of pig production in backyard systems has decreased, compared to other parts of the world where it is carried out in a high percentage (Chauhan *et al.,* 2016). Nevertheless, it is interesting to evaluate the possible effect of this livestock farming activity as reducing and transforming low quality materials, by-products, and waste with strong contaminating potential into high quality animal protein.

The economic analysis showed that producers who combine agriculture and livestock farming activities obtain higher economic income than those who carry out only one activity (Table 3).

Table 3. *Monthly estimated economic analysis in semi-urban areas of the Central Highlands of Mexico*.
Tabla 3. *Análisis económico estimado mensual de los sistemas de traspatios en áreas semi urbano de del Altiplano Central de México*.

Income (US $)	Agriculture n= 54	Livestock farming n=12	Agriculture and livestock farming n= 26
Fruits	14.68	----------	19.58
Vegetables	47.17	----------	20.54
Medicinal plants	5.64	----------	----------
Forages	68.54	----------	14.83
Live chickens	----------	7.59	10.86
Live turkeys	----------	11.01	26.24
Bovines	----------	77.01	116.05
Cow milk	----------	26.17	49.04
Adult pigs	----------	43.35	----------
Piglets	----------	20.44	----------
Fresh cheese	----------	9.10	22.33
Cottage cheese	----------	4.90	12.69
Eggs	----------	16.38	30.14
Pork chorizo	----------	----------	32.22
Sheep barbacoa	----------	58.77	----------
Pork carnitas	----------	85.94	----------
Live rabbits	----------	----------	24.37
Roasted rabbit	----------	----------	35.81
Potential income from unsold products	136.03	360.66	414.71
Potential revenue from unsold products	47.29	70.77	108.57
Total income	183.32	431.43	523.28
Variable costs			
Labor	76.12	227.73	246.36
Manure	10.34	----------	5.49
Fertilizers	6.90	----------	7.94
Seeds	7.93	----------	8.99
Water	5.87	12.23	17.10
Food	----------	68.78	51.48
Vaccines	----------	9.79	7.48
Deworming	----------	3.91	4.50
Other expenses	28.04	9.06	14.45
Total variable costs	135.21	331.50	363.79
Fixed costs			
Depreciation	14.65	25.41	31.09
Administration	5.50	12.94	15.70
Total fixed costs	20.15	38.35	46.79
Total fixed costs	155.35	369.85	410.58
Profits	27.96	61.58	112.71
Benefit-cost ratio	18.00	16.64	27.44

In relation to variable costs, the input that generates the greatest expenditure, both for agricultural and livestock farming activities, is labor. And in backyard systems where livestock farming is practiced, the second most expensive input is food. On the other hand, the depreciation of fixed assets is the greatest expense in fixed costs. Total production costs are higher in backyard systems that carry out agriculture and livestock farming than in those that only carry out one activity.

Regarding profits, all backyard systems have economic gains, in the case of production units that are dedicated to agriculture, for each peso they invest, they earn 18 cents, while those that are dedicated to livestock farming or both earn 16.65 cents and 27.45 cents for each peso invested, respectively. In backyard systems where agriculture, livestock farming, or both activities are developed, economic income is generated by the different products that are sold. The producers who combine agriculture and livestock farming obtain higher income compared to those who carry out only one activity. This agrees with González-Ortiz *et al.,* (2013) who found that the kilograms of vegetable species such as radishes, pomegranates, and peaches have an association of 69 to 89% with the income from products sold, while the kilograms of meat from pigs, sheep, and cattle have a 99 to 100% association with income. Moreover, Salazar-Barrientos *et al.* (2015). This effect is due to the fact that products of animal origin, such as meat, milk, and eggs and products derived from these are more expensive, compared to vegetable products. On the other hand, the income from unsold products corresponds to self-consumption, which means that producers save an expense from the purchase of food, and also receive an economic income that can be used to buy other foods and complement family spending (Kutiwa *et al.,* 2017).

The effect of spending more on labor in agricultural and livestock production systems, or both, is common in production units, generally labor and feeding animals in livestock production (Islam *et al.,* 2015). However, one of the advantages of backyard systems is that 100% of the workforce is family-based, and in the case of feeding poultry and pigs, household food waste is used such as fruit peels, bread waste, tortilla, and corn stubble, or some other agricultural residues for ruminants (Di Pillo *et al.,* 2019), which reduces feeding costs and possible environmental loads of the system. Regarding fixed costs, the greatest expense is the depreciation of some equipment and facilities that producers acquire, such as irrigation equipment, food and drink troughs, animal cages, etc. Total production costs are highest in backyard systems where livestock farming and agriculture are carried out, followed by livestock farming alone, and the lowest production costs are for agriculture alone. This coincides with what was reported by Vagneron (2007), who mentions that generating food of animal origin is up to 8 times more expensive than producing vegetables, rice, and fruits.

Variable costs were higher than fixed costs in backyard systems that carry out agriculture, livestock farming or both activities. This represents an advantage, since the greater amount of expenditure that is made for production happens only if products are being generated in the system, given that in relation to fixed costs, the expense that is actually made is in the acquisition of some installation or equipment used for agricultural or livestock production. Although the cost of administration must be considered, in backyard systems, the owners are the ones who carry out this activity and do not receive a salary. Even considering 3% of the gross income from the sale of products generated as an administration expense in the economic analysis, as indicated by Espinosa *et al.,* (2010), the fixed costs are lower than the variable costs.

Carrying out agricultural activities, livestock farming, or both in backyard systems generates economic profits. When the expense for the payment of labor and administration is not considered, the profits are higher; however, when it is considered, the profits are lower, but positive (Dominguez *et al.,* 2013: Romo *et al.,* 2014). This can be explained by what González *et al.* (2013) state, that backyard systems are a company in which the employer and worker are combined into one person, and that 100% is family labor. In addition, the time that is invested in the activities in this system is very early in the morning and in the afternoons, since 100% of the owners of the systems dedicate themselves to other activities to generate income. Housewives and children who support the daily tasks of the backyard system are engaged in other activities such as housework and going to school, respectively.

Regarding the benefit-cost ratio, when labor expenses are considered, for every dollar that is invested, 18 to 27.45 cents are earned, while when the payment of labor and administration is not considered, for each peso that is invested 39.62 to 67.30 cents are earned. In backyard livestock production systems, the most common species are birds; returns of 2.27 to 2.60% are reported (Islam *et al.,* 2015). Families that carry out backyard agricultural activities, livestock farming, or both, have an economic benefit, since they receive income that generates profits in addition to the savings that they have in purchasing basic food products. Some backyard agricultural systems in urban areas, when labor is accounted for, do not recoup investment costs, or

barely break even. This means they only recover investment costs, without generating profits (Hunold *et al.,* 2017). However, even when economic profits are not generated, farmers guarantee the feeding of their families, with healthy foods.

The farmers in the backyard systems in the study area carry out agricultural and livestock activities with empirical knowledge. To improve these systems, training is required in the different areas that agricultural and livestock production involves, beginning with the use of records of information, since these are of vital importance to make a productive and economic quantitative evaluation (Espinosa-Garcia *et al.* 2010), to know exactly the quantities of food that it generates, the inputs in which they make their investment, as well as the income obtained for each food generated, as has begun to be done in small-scale units producing meat and milk (Uddin *et al.,* 2010; Posadas Dominguez *et al.,* 2013).

4. Conclusions

Backyard systems in the semi-urban region of the Central Highlands of Mexico and surroundings generate food products of plant and animal origin, which are mainly for self-consumption and sale. The benefits they obtain are savings in the cost of food from the basic basket, in addition to positive economic profits from both agricultural and livestock activities, the farmers who carry out both activities generate greater economic benefits, which makes these production units profitable by recover your investment expenses.

The production of food of plant and animal origin in the backyard system is an option to achieve food sovereignty, reduce poverty in urban and semi-urban areas, however, they require technical training, keep track of production records and financial and advice for the marketing of their products.

5. Supplementary information

There aren't additional information

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Interest conflict

The authors declare that there is no conflict of interest.

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